UNCLASSIFIED

AD 414350

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

CATALOGED BY DDC
AS AD NO. 41435
41435

CHARTS FOR THE PARAMETERS OF MIGRATING EXPLOSION BUBBLES

15 OCTOBER 1962



UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 62-184

RELEASED TO ASTIA
BY THE MAYAL ORDNANCE LABORATORY
Without restrictions
For Roleage to Military
Agencies Only Wo

Agonotes Only Wo L

Approval by Burops required for release
to contractors.

Approval by Buweps required for all subsequent release.

CHARTS FOR THE PARAMETERS OF MIGRATING EXPLOSION BUBBLES

Ву

H. G. Snay and Ruth V. Tipcon

ABSTRACT: Graphs are presented for the relative bubble energies, maximum radii, periods, and migrations of underwater explosion bubbles for four cycles of the bubble oscillation. The migration refers to the bubble maximum in each cycle. The position of the bubble minimum can be readily found by a simple computation. The graphs permit a convenient reading of these parameters for a wide range of conditions.

PUBLISHED SEPTEMBER 1963

EXPLOSIONS RESEARCH DEPARTMENT U.S. NAVAL ORDNANCE LABORATORY White Oak, Silver Spring, Maryland

15 October 1962

CHARTS FOR THE PARAMETERS OF MIGRATING EXPLOSION BUBBLES

This report is part of a comprehensive study on the behavior of explosion gas bubbles which has been carried out under Task No. 301-664/43003/01040 and RUME-3-E-000/212-1/WF 008-10-004 PA 002. A knowledge of the behavior of migrating gas bubbles is of considerable importance in studies of ship damage. NAVORD Report 3906, "Key Problems in Explosive Research and Development", Chapter III, "Anti-Submarine Warfare" discusses this in more detail. The present report represents a numerical evaluation of the theory developed in NAVORD Report 4185. The charts prepared on the basis of this theory provide a simple method which this Laboratory believes will save considerable time and effort in calculating the important characteristics of explosion bubbles in the second and subsequent cycles of the pulsation.

The major portion of this work was carried out during a course of duty of the second author as a junior professional trainee.

R. E. ODENING Captain, USN Commander

01

C. J. ARONSON
By direction

CONTENTS

					Page
				OF MIGRATING BUBBLES	
				CULATIONS	
	US	E O	f the GRA	APHS	
. •	TH	EE	FFECT OF	THE WATER SURFACE	4
REFE	ŒN	CES	S		14
				ILLUSTRATIONS	
Figu	re	1	Relative	Depth at Second Bubble Maximum	6
Figu	re	2	Relative	Depth at Third Bubble Maximum	
Figu	re	3	Relative	Depth at Fourth Bubble Maximum	
Figu	re	4	Relative	Second Bubble Period	. 9
Figu	re	5	Relative	Third Bubble Period	10
Figu:	re	6	Relative	Fourth Bubble Period	. 11
Figu	re	7	Relative	Maximum Radii	. 12
Figu:	re	8	Relative	Bubble Energies	. 13

HOLTR 62-184

I. INTRODUCTION

In NAVORD Report 41.85* relationships are derived for the migration and energy ratios of underwater explosion bubbles. The data given in that report are sufficient to provide the information needed for calculating the migration period, maximum radius, and energy through the 4th cycle. In the present report this information has been used to make graphs for the ratios of these parameters. The use of non-dimensional variables permits the convenient reading of the results for a wide range of explosive conditions.

II. THE EQUATIONS OF MIGRATING BUBBLES

The equation for the migration for pulsating bubbles between the nth and (n + 1)th bubble maximum derived in NAVORD Report 4185 (Equation 9) can be written in the following form

$$\frac{z_{n}-z_{n+1}}{z_{1}} = \frac{\Delta z_{n}}{z_{1}} = c \left(\frac{z_{n}}{z_{1}}\right)^{3/2} \left(\frac{z_{n}}{z_{1}}\right)^{1/2} \frac{z_{1}}{z_{n}} \left[1 - \frac{z_{n}}{z_{1}}\right]^{1/3} \left(\frac{z_{1}}{z_{n}}\right)^{2} \left(\frac{z_{n}}{z_{1}}\right)^{2/3} , \qquad (1)$$

where

Z = Total hydrostatic pressure measured in feet of water.
 1 atmosphere = 33 ft sea water = 34 ft fresh water

 ^{A}M = Maximum bubble radius in ft.

r = Ratio of bubble energy to the total energy of explosion.

n = Subscript designating the cycle of the pulsation.

D = Depth in ft below the water surface. D refers to the center of the bubble maximum. In the first cycle, D_1 is assumed to be equal to the depth of explosion, i.e. the migration up to the first bubble maximum is neglected.

^{*} Full reference is given at the end of this report.

It is stated in NAVORD 4185 that C can be considered to be a universal constant, C = 3.5.

From(1) it appears that $\Delta Z_n/Z_1$ is a function of A_{M1}/Z_1 , Z_n/Z_1 , D_n/Z_1 and r_n/r_1 . The energy ratio r_n/r_1 is evaluated in NAVORD 4185 and is shown to be a function of $\Delta Z_n/Z_n$. The two variables Z_n/Z_1 and D_n/Z_1 are functions of the reduced migration $\Delta Z_n/Z_1$, as can be seen in the following relations:

$$\frac{z_{n}}{z_{1}} = \frac{z_{n-1}}{z_{1}} - \frac{\Delta z_{n}}{z_{1}} \tag{2}$$

and

$$\frac{D_n}{Z_2} = \frac{D_{n-1}}{Z_2} - \frac{\Delta Z_n}{Z_2}.$$
 (3)

Therefore, the reduced migration and the depths of the later bubble maxima are functions of two variables only, namely $A_{\rm Ml}/Z_1$ and $D_{\rm l}/Z_1$. This fact permits a convenient graphical representation not only of the migration, but also of the other bubble parameters.

The equation for the first maximum bubble radius is, reference (b).

$$A_{ML} = J\left(\frac{W}{Z_1}\right)^{1/3}, \qquad (4)$$

where

W = Charge weight in lbs.

J = Radius constant dependent on the properties of the explosive, e.g. J = 12.6 for TNT, reference (c).

The maximum radius at any one of the subsequent cycles is given by

$$\frac{A_{Mn}}{A_{Mn}} = \left(\frac{r_n}{r_1} \frac{z_1}{z_n}\right)^{1/3}, \text{ (NAVORD 4185, Equation 4)}.$$
 (5)

The period of the first bubble pulsation for an explosion in infinitely deep water is, reference (b),

$$T_1 = K \frac{w^{1/3}}{z_1^{5/6}} \left[1 - 0.1 \frac{A_{M1}}{D_1}\right],$$
 (6)

where K is the period constant, e.g. K=4.36 for TNT, reference (c). The term 0.1 $A_{\rm Mn}/D_{\rm n}$ accounts for the effect of the water surface on the pulsation. It is negligibly small for a deep explosion, but compensates for the shorter periods of a bubble pulsating near the water surface. (Compare Section III of NAVORD 4185 about the value 0.1.)

The periods of the subsequent cycles can be obtained from

$$\frac{T_n}{T_1} = \left(\frac{r_n}{r_1}\right)^{1/3} \left(\frac{Z_1}{Z_n}\right)^{5/6} \frac{1 - 0.1 A_{Mn}/D_n}{1 - 0.1 A_{Mn}/D_1}, \tag{7}$$

as discussed in NAVORD 4185, Equation (2).

Since (5) and (7) contain only parameters which are functions of A_{Mn}/Z_1 and D_1/Z_1 , the period and radius ratios are functions of these two variables only and each can be graphically presented by means of a family of curves.

For shallow explosions, the presence of the water surface perturbs the bubble oscillation in such a way that the emission of the bubble pulse ceases. This phenomenon is commonly called venting of the bubble or blowin. It can be quantitatively taken into account using the evidence that the nth bubble pulse will not occur when

$$A_{Mn} \leq 1.1 D_n. \tag{8}$$

III. NUMERICAL CALCULATIONS

The calculations of this paper are based on the relationships listed above and the values of $r_{\rm n}/r_{\rm l}$ found in NAVORD Report 4185. The ratios for the depths of the bubble maximum, the periods, the maximum radii, and the bubble energies were calculated for the first four cycles of the oscillation. In view of the uncertainty of the energy ratio for the 5th cycle, given in NAVORD 4185, this case was not included. Graphs were made using $A_{\rm Ml}/Z_{\rm l}$ as abscissas and the above bubble parameters as ordinates. The result is presented as a family of curves each labelled by a value $D_{\rm l}/Z_{\rm l}$.

Limiting curves were constructed for the condition where blow-in occurs, Figures 1 to 3. In the other charts the points of blow-in are marked. The continuation of the curves beyond these points is shown in dashed lines. They are useful for certain calculations, although for such conditions no bubble pulse occurs.

IV. USE OF THE GRAPHS

Given the weight of the explosive charge W and the depth D_1 at which it is fired, one uses the formulae

$$\frac{D_1}{Z_1} = \frac{D_1}{D_1 + 33} \tag{9}$$

$$\frac{A_{M1}}{z_1} = J \frac{w^{1/3}}{z_1^{14/3}} \tag{10}$$

to find the input of the charts. The ratios read from the graphs are multiplied with the value of the corresponding variable for the first cycle of the oscillation. This immediately yields the desired result.

As an example suppose one desires to know the depth of the third bubble maximum of a 290-lb TNT charge fired at a depth of 150 ft in sea water. Here, $Z_1 = 150$ ft + 33 ft = 183 ft. Using (10) one finds $A_{\rm M1}/Z_1 = 0.0803$ and from (9) $D_1/Z_1 = 0.82$. The first period is according to (6) $T_1 = 0.372$. Using these values one finds from Figure 2: $D_3/D_1 = 0.830$ and $D_3 = 125$ ft. Thus, the upward migration of the bubble from the initial charge location up to the moment of the third bubble maximum has been 25 ft. In an analogous way one finds from Figure 5: $T_3/T_1 = .75$, and $T_3 = 0.279$ seconds. The period T_3 refers to the time between the second and third bubble minimum. The time of the third maximum would be $T_1 + T_2 + T_3/2 = 0.834$ seconds. The position of the third bubble minimum can be found by calculating that of the fourth bubble maximum and placing the bubble minimum half way between these two maxima.

V. COMMENTS ON THE DEPENDENCY OF THE BUBBLE PARAMETERS ON THE EFFECT OF THE WATER SURFACE

Inspection of the graphs presented in this report gives an interesting insight on the influence which the two input variables have on the bubble behavior.

The magnitude $A_{\rm Ml}/Z_{\rm l}$ is a measure of the buoyancy of the bubble. The maximum radius used in this ratio represents the pressure difference between bubble top and center. It is this type of pressure difference which, when integrated over the bubble surface, produces buoyancy. $Z_{\rm l}$ stands for the total pressure at the bubble center. Hence, $A_{\rm Ml}/Z_{\rm l}$ represents one-half of the pressure difference between bubble top and bottom divided by the pressure at the center. This magnitude accounts for the driving force of the gravity migration.

The other variable, D_1/Z_1 , is a measure of the depth at which the explosion occurs. The deeper the explosion, the closer is this value to unity.

Comparing the above equations, it is seen that D_1/Z_1 occurs in the surface correction terms only. Hence, A_{M1}/Z_1 is a measure of the strength of migration, and D_1/Z_1 is a measure of the surface effect.

The graphs illustrate the importance of these two effects on the bubble parameters. Figures 1 to 3 represent the migration. The large spread of the family of curves in this figure indicates that the surface effects have a strong bearing on migration. The influence is less pronounced for the bubble periods, Figures 4 to 6, but still clearly noticeable. This evidence was to be expected, since equations (1) and (6) include surface correction terms. But, the surface effect also enters into the computation of the maximum bubble radius and the bubble energy, although these terms are not directly affected by the water surface. The curves for the maximum radii, Figure 7, show this influence only for close proximities of the bubble to the water surface: The curve for each reduced depth D_1/Z_1 emerges from the average curve near the point of blow-in or for very shallow conditions. The same effect is noticeable for the bubble energy ratio, Figure 8.

This discussion illustrates the importance of the surface effect and shows that it must not be neglected in a study of bubble migration. The charts presented in this paper quantitatively account for this effect and, at the same time, allow for a convenient appraisal of its significance. For instance maximum radius, bubble energy, and periods depend mainly on $\rm A_{Ml}/\rm Z_{l}$. On this basis, simple approximate formulae could be set up which give these magnitudes as functions of $\rm A_{Ml}/\rm Z_{l}$ only. The charts illustrate the limited accuracy of such approximations. Since reading of a graph is simpler than to evaluate equations, we have not included such formulae in this report.

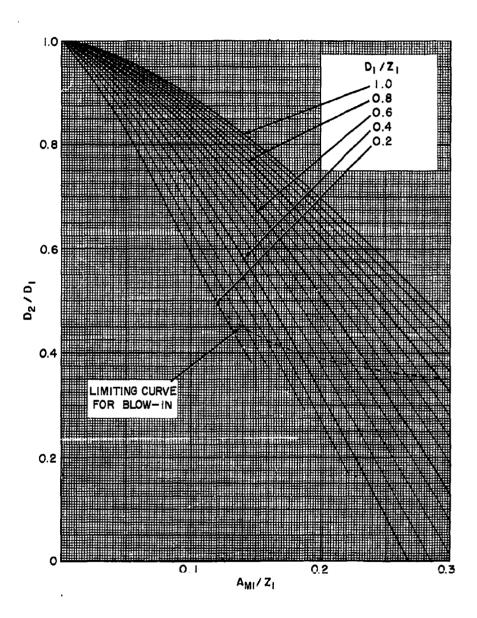


FIG.I RELATIVE DEPTH AT SECOND BUBBLE MAXIMUM

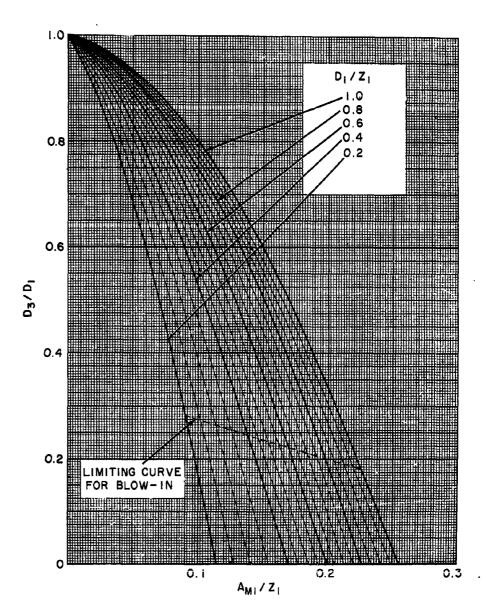


FIG. 2 RELATIVE DEPTH AT THIRD BUBBLE MAXIMUM

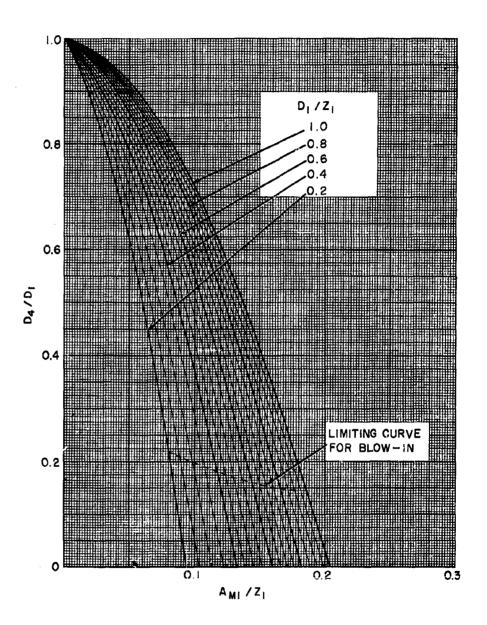


FIG. 3 RELATIVE DEPTH AT FOURTH BUBBLE MAXIMUM

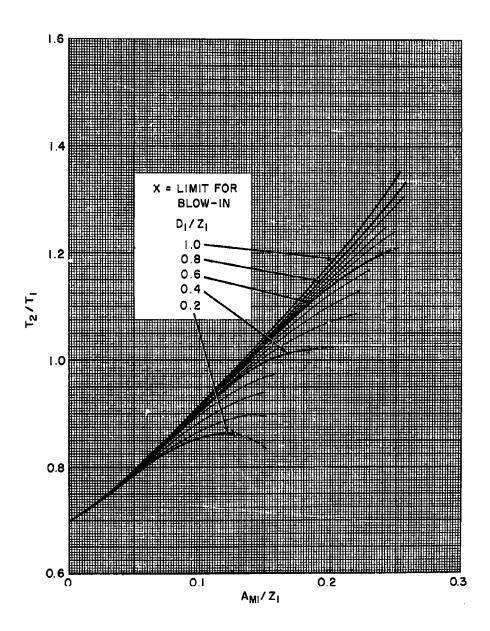


FIG. 4 RELATIVE SECOND BUBBLE PERIOD

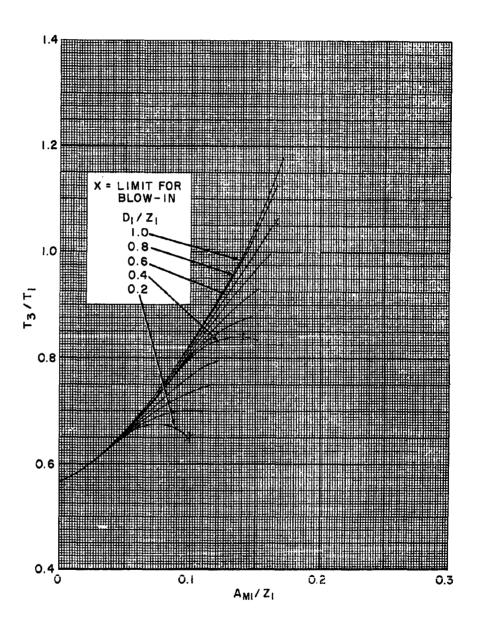


FIG. 5 RELATIVE THIRD BUBBLE PERIOD

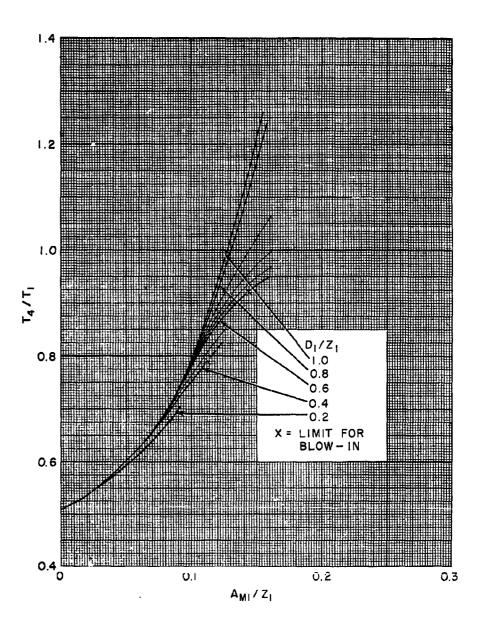


FIG. 6 RELATIVE FOURTH BUBBLE PERIOD

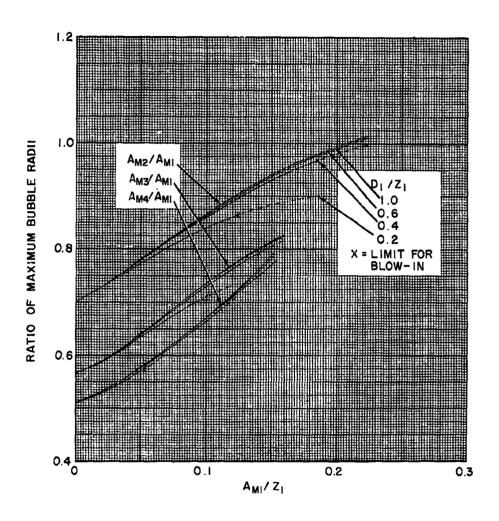


FIG. 7 RELATIVE MAXIMUM BUBBLE RADII
D₁/Z₁ LABELS ARE ONLY SHOWN FOR THE
UPPER FAMILY OF CURVES. LABELS FOR THE
OTHER CURVES ARE ANALOGOUS

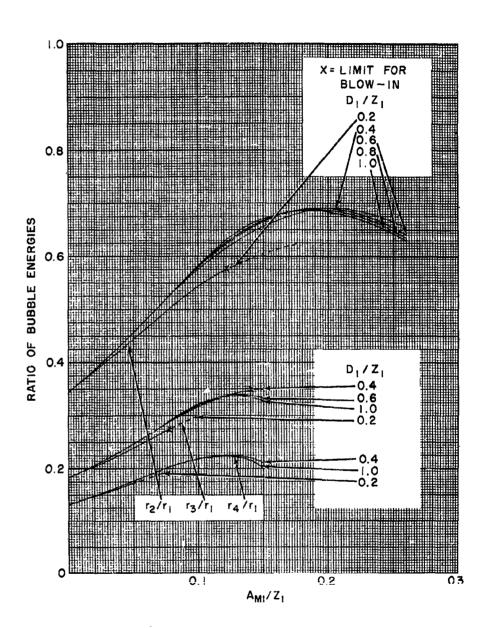


FIG. 8 RELATIVE BUBBLE ENERGIES

NOITR 62-184

REFERENCE

- (a) "Underwater Explosion Phenomena: The Parameters of Migrating Bubbles", H. G. Snay, NavOrd Report 4185, 12 October 1962, Unclassified.
- (b) "Underwater Explosions. A summary of Results", E. H. Kennard, DTMB Report C-334, February 1951, Confidential.
- (c) "Explosion Effects Data Sheets", NavOrd Report 2986, 14 June 1955, Confidential.

DISTRIBUTION

	Copies
Chief, Bureau of Naval Weapons, Attn: Tech Lib. DIS3	4
Attn: RUME_3	1
Attn: RRRE-5	1
Chief of Naval Operations, Attn: OP-715	1
Chief of Naval Research, Attn: Code 466	1
Code 418	1
Code 429	1
Code 425	2
Chief, Bureau of Ships, Attn: Code 423	2
Chief, Bureau of Yards and Docks	1
Commanding Officer and Director, U. S. Naval Radiological Defense	
Laboratory, San Francisco 24, California, Attn: Code 911	1
Attn: Code 934	1
Attn: Code 222	1
Commanding Officer, Naval Propellant Plant, Indian Head, Maryland	1
Commander, Naval Weapons Laboratory, Dahlgren, Virginia	
Attn: Experimental Officer	1
Commander, Naval Ordnance Test Station, China Lake, California	
Attn: Technical Library	1
Commander, Naval Ordnance Test Station, Pasadena, California	1
Director, Naval Research Laboratory, Washington, D. C.	2
Commanding Officer & Director, David Taylor Model Basin,	
Washington 7, D. C.	2
Commanding Officer & Director, David Taylor Model Basin,	
Underwater Explosions Research Division, Portsmouth, Virginia	
(Code 780)	1
Superintendent, U. S. Naval Postgraduate School, Monterey, California	. 1
Director, U. S. Navy Electronics Laboratory, San Diego, California	1
Commanding Officer, U. S. Naval Underwater Ordnance Station,	
Newport, Rhode Island	1
Commander, U. S. Naval Weapons Station, Yorktown, Virginia	
Attn: Research and Development Division	1
Commanding Officer, Naval Torpedo Station, Keyport, Washington	1
Commanding Officer and Director, U. S. Navy Underwater Sound	
Laboratory, New London, Conn.	1
Commanding Officer, U. S. Naval Air Development Center,	
Johnsville, Pennsylvania	1
Commanding Officer, U. S. Naval Ammunition Depot, Navy Number 66,	
Fleet Post Office, San Francisco, California,	
Address One 1 days Free Treated on Tehometows	1

Commander, U. S. Naval Oceanographic Office	*
Washington 25, D. C.	l
Commanding Officer, U. S. Navy Mine Defense Laboratory,	
Panama City, Florida	1
Commanding Officer & Director, Naval Civil Engineering Laboratory	
Port Hueneme, California	1
Commanding Officer, U. S. Naval Weapons Evaluation Facility,	
Kirtland Air Force Base, Albuquerque, New Mexico	1
Chief of Research and Development, Department of the Army,	
Washington, D. C.	1
Chief of Ordnance, Department of the Army, Washington, D. C.	2
Chief of Engineers, Department of the Army, Washington, D. C.	
Attn: ENGNB	2
Attn: ENGEB	1
Director, Waterways Experiment Station, Vicksburg, Mississippi	
Attn: F. R. Brown	1
Commanding General, Ballistic Research Laboratories,	
Aberdeen, Maryland	1
Commanding Officer, Picatinny Arsenal, Dover, New Jersey	1
Commanding Officer, Engineer Research and Development Laboratory,	
Fort Belvoir, Virginia, Attn: Chief, Tech. Support Branch	1
Commanding Officer, USA Signal R and D Laboratory,	
Fort Monmouth, New Jersey, Attn: Tech. Documents Center	1
Director of Research and Development, Headquarters, U. S. Air	
Force, Washington 25, D. C.	1
Commander, Ocama, Attn: Air Force Ammunition Services Office,	
Hill Air Force Base, Utah	1
Headquarters, Air Proving Ground Center, U. S. Air Force, ABNC,	
Eglin Air Force Base, Florida	
Attn: PGTRI, Tech Lib.	1
Commander, Air Force Logistics Command, Wright-Patterson Air Force	
Base, Dayton, Chio	1
Aeronautical System Division, Wright-Patterson Air Force Base,	
Dayton, Ohio	1
Commander, Air Force Special Weapons Center, Kirtland Air Force	
Base, Albuquerque, New Mexico, Attn: Technical Library	1
Director, Defense Research and Engineering, Washington 25, D. C.	_
Attn: Technical Library	1
Director, Applied Physics Laboratory, Johns Hopkins University,	_
Silver Spring, Maryland	1
Chief, Defense Atomic Support Agency, Washington 25, D. C.	3
Director, Applied Physics Laboratory, University of Washington,	_
Seattle, Washington	1
Chief of Naval Operations, Washington 25, D. C. (Op 754)	1

Research Analysis Corporation 6935 Arlington Road Bethesda, Maryland	
Washington 14, D. C.	J
Director, Ordnance Research Laboratory, Pennsylvania State	
University, University Park, Pennsylvania	1
Director, Woods Hole Oceanographic Institution, Woods Hole, Mass.	2
Director, Scripps Institute of Oceanography, La Jolla, California Columbia University, Hudson Laboratories, 145 Palisade Street,	2
Dobbs Ferry, N. J.	1
Director, Lawrence Radiation Laboratory, Livermore, California Director, Los Alamos Scientific Laboratory, Los Alamos,	1
New Mexico, Attn: Dr. D. P. MacDougall	2
Director, National Bureau of Standards, Washington, D. C.	
Attn: Security Officer	ı
Administrator, NASA, 1512 H Street, N. W., Washington, D. C.	1
Sandia Corporation, Sandia Base, Albuquerque, New Mexico	
Attn: Classified Document Division	1
Armed Services Technical Information Agency, Arlington Hall Station, Arlington 12, Virginia, Attn: TIPDR	10
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts Attn: Dr. Arnold Arons	1
Radio Standards Laboratory, National Bureau of Standards, Radio	
Physics Division (Div. 91), Attn: Dr. George E. Hudson	1
Michigan State University, East Lansing, Michigan	
Attn: Dr. T. Triffet, Dept. of Applied Mechanics	1
Harvey Mudd College, Claremont, California	
Attn: Dr. A. B. Focke, Dept. of Physics	1
Columbia University, New York 27, New York, Attn: Dr. Hans H. Eleich, Dept. of Civil Engr. and Engr. Mech.	1
Office of Technical Services, Department of Commerce,	
Washington 25, D. C.	100
United Research Services Incorporated, Physical Sciences Division,	
1811 Trousdale Drive, Burlingame, California	_
Attn: Mr. Kenneth Kaplan, Deputy Director	1
National Marine Consultants	
707 East Vermont Avenue	1
Anaheim. California	1

CATALOGING INFORMATION FOR LIBRARY USE

			ő	BIBLIOGRAPHIC INFORMATION	INFORMATION			
	DESCRIPTORS	IPTORS	_	CODES			DESCRIPTORS	cobes
SOURCE	NOL technical report	port		NOLTR	SECURITY CLASSIFICATION AND CODE COUNT		Unclassified - 24	uøzh
REPORT NUMBER	62-184			62Ø184	CIRCULATION LIMITATION	NTION		
REPORT DATE	15 October 1962	•		1062	CIRCULATION LIMITATION OR BIBLIOGRAPHIC	VTION		
					BIBLIOGRAPHIC (SUPPL., VOL., ETC.)			
) N	UBJECT ANAL	SUBJECT ANALYSIS OF REPORT			
	DESCRIPTORS	CODES		DESCRIPTORS		CODES	DESCRIPTORS	CODES
Charts		CHRS	Cycles			CYCE		
Migrating	bn	MIGR	Oscillation	ion	-	OSCA		
Explosion	ជ	EXPS	Position			POSO		
Bubbles		BUBB	Computation	ion		сома		
Parameters	rs	PARA	Gas			GASE		
Underwater	er	UNDE	Bubbles (behavior)	(behavior		BUBBZ		
Energies		ENER	Equations	10		EQUA		
Maximum		MAXM	Numerical	1		NUMB		
Minimur		MILIM	Dependency	су		DEPN		
Radii		RAUS	Water			WATR		
Periods		DURT	Surface			SURA		
Four	:	FOUT	Phenomena	ត	-	PHEO		
PRINCMOL5070,728 (5-62)	(5-62)							

Explosions, Underwater Bubbles, Explosion Bubbles Measurement Title Snay, Bans G. Tipton, Ruth V., ft. suthor Project	Explosions, Underwater Explosion Bubbles - Migration Bubbles Measurement Title Snsy, Hans G. Tittle Tittle Froject
1 2 % 4 HH FP	7. %
Mayal Ordnance Laboratory, White Oak, Md. (NDL technical report 62-184) CHARTS FOR THE PARAMETERS OF MIGHATING EX- FLOSION BUFBLES, by H. G. Shay and Ruth V. Tipton. 1-p. 15 Oct. 1962. Buffers tasks 301-66443003/01040 and RUME-3-E-000/212-1/ NF 008-10-004 PA 002. UNCLASSIFIED Graphs are presented for the relative bubble I. energies, maximum radii, periods, and migrations of underwater radios bubbles for four tions of underwater radios bubbles for four tions of underwater socialisation. The migration refers to the bubble maximum in each sycle. The position of the bubble minimum can V. be readily found by a simple computation. The graphs permit a convenient reading of these parameters for a wide range of conditions.	Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 62-184) CHERTS FOR THE PARAGTERS OF MIGHALING EX- PLOSION BUBBLES, by H. G. Snay and Ruth V. Tipton. 14p. 15 Oct. 1962. Buffeps tasks 301-664/43003/01040 and RUME-3-E-000/212-1/ WF OOS-10-004 PA 002. UNCLASSITIED Graphs are presented for the relative bubble I. energies, maximum radii, periods, and migra- tions of underwater explosion bubbles for four tion refers to the bubble oscillation. The migra- tion refers to the bubble maximum in each cycles of the bubble oscillation. The migra- tion refers to the bubble maximum in each cycle. The position of the bubble minimum can be readily found by a simple computation. The graphs permit a convenient reading of these parameters for a wide range of conditions.
Explosions, Underwater Underwater Bubbles, Explosion Bubbles Migration Bubbles Measurement Title Snay, Hans G. Tilyton, Ruth V., Jt. author Project	Explosions, Underwater Bubbles, Explosion Bubbles - Migration Bubbles - Measurement Title Snsy, Eans G. Tilyton, Ruth V., jt. author Project
7. % 4. HH 7. %	- 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
Naval Ordnance Laboratory, White Oak, M4. [NOL technical report 62-134] CHARTS FOR THE PARAMETERS OF MIGHALING EX- HOSION BUBBLES, by H. G. Snay and Ruth V. Thyten 14p. Thyten 14p. Thyten 14p. Thyten 14p. Though and RUKE-3-E-COO/212-1/ WF COS-10-CO4 PA CO2. UNGLASSIFIED Graphs are presented for the relative bubble I. energies, naximum radii, periods, and migrangoles of the bubble excluding and migrangoles of the bubble maximum in each cycles of the bubble maximum in each cycle. The position of the bubble minimum can be readily found by a simple cumputation. The graphs permit a convenient reading of these parameters for a wide range of conditions.	Naval Orduance Laboratory, White Oak, Md. (NOL technical report 62-184) CHARTES FOR THE PARAMETERS OF MIGHATHES EX- FLOSION BUBBLES, by H. G. Sney and Ruth V. Tipton. 140. Tipton. 164. Tipton. 164. Tipton. 164. Tipton. 164. Tipton of PA 002. UNCLASSIFIED Graphs are presented for the relative bubble I. energies, maximum radii, periods, and migrations of underwater explosion bubbles for four III. tions of underwater explosion bubbles for four III. tyon refers to the bubble maximum in each oycle. The position of the bubble minimum can V. be readily found by a simple computation. The graphs permit a convenient reading of these parameters for a wide range of sonditions.

.

:

. .

1. Explosions, Underwater Explosion 3. Bubbles - Migration 4. Bubbles - Meaurement I. Title II. Snay, Haus G. III. Snay, Haus IV. Project V. Project	1. Explosions, Underwater Underwater Bubles, Explosion 3. Bubles - Migration Sasy, Hans G. III. Tipton, Huth Y., Hroject V., Project V.
Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 62-184) CERRES FOR THE PRAMETERS OF MIGRATING EX- FLOSION BUBBLES, by H. G. Snay and RUR by, Tipton. 14p. 15 Oct. 1962. Bulweps tasks 301-664/43003/01040 and RUME-3-E-000/212-1/ WF 008-10-004 PA 002. UNCLASSIFIED Graphs are presented for the relative bubble I., energies, maximum radii, periods, and migra- energies, maximum radii, periods, and migra- tions of underwater explosion bubbles for four tions of the bubble oscillation. The migra- tion refers to the bubble maximum in each cycles. The posttion of the bubble minimum can be be readily found by a simple computation. The parameters for a wide range of conditions.	(Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 62-184) CHARTS FOR THE PARAMETERS OF MIGRATING EX- FIOSION BUBBLES, by H. G. Snay and Ruth V. Tipton. 14p. 15 Oot. 1962. Buffers tasks 301-664/43003/01040 and RUME-3-E-000/212-1/ WF OOS-10-004 PA OO2. Graphs are presented for the relative bubble increases, maximum radii, periods, and migrantions of underwater explosion bubbles for four tion refers to the bubble maximum in each cycle. The position of the bubble minimum can be realily found by a simple computation. The graphs permit a convenient reading of these parameters for a wide range of conditions.
1. Explosions, Underwater 2. Bubbles, Explosion 3. Rigration 4. Bubbles - Measurement I. Hitle II. Snay, Eans G. III. Tipton, Ruth V., jf. author V., Froject V. Froject	1. Explosions, Underwater 2. Bubbles, Baplosion 3. Bubbles - Maration 4. Bubbles - Masurement I. Hitle II. Saay, Hans G. III. Tipton, Ruth V., fr., fr., exthor V., Froject V. Project
Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 62-184) CEARTS FOR ITH PALAMETERS OF MIGRATING EX- FLOSION BUBBLES, by H. G. Snay and Ruth V. Thyton. 14p. 15 Oct. 1962. 39Weps tasks 301-664/4503/01040 and RUME-3-E-000/212-1/ WF OO8-10-304 PA 002. UNCLASSIFED Graphs are presented for the relative bubble if energies, maximum radii, periois, and migrations of underwater explosion bubbles for four cycles of the bubble oscillation. The migration refers to the bubble maximum in each oyole. The position of the bubble minum can graphs permit a convenient realing of these parameters for a wide range of conditions.	Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 62-184) CHARTS FOR THE PARAMETERS OF MIGRATING EX- PLOSION BUBBLES, by H. G. Snay and Ruth V. Tipton., 14p. 15 Oct. 1962. Bulleys tasks 301-664-3003/01040 and RUME-3-E-COO/212-1/ WF OOS-10-CO4 PA OC2. UNCLASSIFIED Graphs are presented for the relative bubble energies, maximum radii, periods, and migrations of undermater explosion bubbles for four ILL cycles of the bubble maximum in each oyole. The position of the bubble maximum on Energity found by a simple computation. The graphs permit a convenient residing of these parameters for a wide range of conditions.

: